# Annual Report

of the

# Director of the Bureau of Standards

to the

Secretary of Commerce and Labor

for the

Fiscal Year Ended June 30, 1909

Washington
Government Printing Office
1910

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DEPARTMENT OF COMMERCE AND LABOR,
BUREAU OF STANDARDS,
*Washington, July 1, 1909.*

SIR: I have the honor to submit the following report of the work of the Bureau of Standards for the fiscal year ended June 30, 1909:

## DIVISION I—ELECTRICITY.

Electrical measuring instruments, of which a great variety of types and sizes are employed in the measurement of electrical current, voltage, and power, are tested by comparing them with certain standard instruments which have been carefully investigated and which are referred back from time to time to the fundamental electrical standards which it is one of the functions of the Bureau to establish and maintain. These fundamental electrical standards represent the unit of resistance and the unit of electromotive force or voltage, the values of which, and their method of preparation, are fixed by law. They are not, however, chosen arbitrarily, but are so specified as to be simply related to the absolute units of resistance and voltage, which latter are logically derived from the fundamental units of length, mass, and time—that is, the centimeter, the gram, and the second.

The experimental realization of suitable concrete electrical standards involves two distinctly different steps or stages—first, the determination of their values by means of what are called "absolute electrical measurements," in which is demanded the complete theory of the methods and instruments employed, the most perfect instrumental equipment, and experimental skill of a high order; second, the development of concrete material standards by means of which the values found in these elaborate absolute measurements may be permanently preserved.

This work was first done (chiefly by European investigators) a generation ago, and our present legal values were fixed on the recom-

mendation of the International Electrical Congress of 1893. But subsequent work has shown that the values then adopted were not as accurate as they were supposed to be, and whereas England, France, America, and some other countries have continued to employ the values then chosen, Germany, Austria, and other countries have used slightly different units for the measurement of current and voltage.

The International Electrical Conference which met in London in October, 1908, adopted a new value for the unit of electromotive force, but left to a newly constituted international committee the completion of the specifications of the concrete standards, inasmuch as agreement could not be reached at the conference. This committee of twenty members represents eleven different countries, three of the four American members, including the secretary and treasurer of the committee, being from the Bureau of Standards.

In order to settle some of the disputed questions involved, and to clear up some of the obscure points at issue, the international committee has arranged to have an international cooperative investigation undertaken by representatives of some of the largest national standardizing institutions, including this Bureau; and at our invitation the work is to be carried out during the coming fiscal year at the Bureau of Standards. This work is of prime interest and importance, and will probably go far toward securing not only greater precision, but, what is even more important, international uniformity among the civilized nations of the world in electrical units and standards.

In view of the international conference of last October and the approaching international cooperative investigation, considerable work has been done during the year on the subject of electrical standards and absolute electrical measurements.

### RESISTANCE AND ELECTROMOTIVE FORCE.

Although the London International Electrical Congress selected the ohm and the ampere as the fundamental electrical units in terms of which all electrical measurements are to be expressed, the Bureau has found it impracticable to adopt the recommendations, owing to variations still found in coulometer measurements, which are at present under investigation. The results of electrical measurements will therefore be referred to the basis of reference heretofore employed, namely, the ohm and the Weston standard cell.

During the past year considerable progress has been made in the construction of primary mercurial resistance standards. The calibration of a number of carefully selected capillary tubes has been completed, and considerable preliminary work has been done in other directions.

Further work has been done in cooperation with the Chemical Division in the investigation of equilibrium conditions in the Weston normal cell, which have been called into question, and some promising results have already been obtained. The comparison of standard cells, set up during the past year, at the English National Physical Laboratory and by other investigators has verified the accuracy of reproduction claimed in former reports—several parts in 100,000.

An investigation of the conductivity and temperature coefficient of copper and aluminum had been undertaken at the request of the committee on standards of the American Institution of Electrical Engineers and of a number of copper refiners and wire manufacturers who have generously offered to cooperate with the Bureau in furnishing and drawing samples. This work will include an investigation of commercial and specially prepared materials, the influence of traces of added impurities which so largely affect the conductivity, and the influence of drawing and annealing.

An experimental and theoretical study has also been made of the vibration galvanometer used in precision measurements with alternating currents and has resulted in improvements which further increase its already high sensibility.

The above investigations will be continued as far as permitted by the routine testing of apparatus submitted for certification, the volume of which has shown a steady increase since the organization of the Bureau.

### INDUCTANCE AND CAPACITY AND ABSOLUTE MEASUREMENTS.

The work on the absolute measurement of electric current has been continued during the year and a new value obtained for the electromotive force of the Weston normal cell. An investigation of the silver coulometer is being carried out, which promises to yield results of much scientific value. A new method for the absolute measurement of resistance has been devised, and the necessary apparatus constructed; work of carrying out the measurements will be done during the next fiscal year. Investigations of inductances and condensers have been continued. Tests have also been made of standards of inductance and capacity and of electrical instruments. The work in this section touches the practical application of electricity less directly than in other sections of the Electrical Division, being largely concerned with the fundamental measurements which underlie practical applications.

### MAGNETIC MEASUREMENTS.

The principal demands for magnetic testing comprise tests to determine the magnetic permeability of specimens and to determine the energy losses occurring in the magnetic material used in the con-

struction of electrical apparatus, such as dynamos, motors, and transformers. Improved methods for conducting both of these tests have been in the course of development for some time, and have now reached a satisfactory stage. Circular No. 17 has been issued, announcing the readiness of the Bureau to conduct magnetic tests for the public and prescribing the conditions under which tests are made.

The Bureau has prepared a number of bars of different grades of steel, and different sizes, whose magnetic properties have been carefully determined. These are supplied to the public, when desired, for the purpose of checking magnetic measurements made with commercial or other apparatus.

Preparations have been made for testing the spirals of bismuth wire which are used for the measurements of intense magnetic fields, and several of these spirals have been tested. Special investigations were completed during the year to determine the effects of high temperatures and of low temperatures upon the magnetic properties of manganese-steel, the alloy used being one which is very nearly non-magnetic; to determine the errors incident to testing material in the form of rings; to discover whether the energy losses due to alternating magnetization are dependent upon the wave form of the electrical current used for magnetizing, and to determine the relative merits of silicon-steel and ordinary steel for use in electrical transformers.

## ELECTRICAL MEASURING INSTRUMENTS.

The demands made by the public upon the Bureau for the testing of this class of apparatus have increased considerably during the past year. In addition to standard instruments regularly tested in the past, the work of testing current and potential transformers has been considerably extended; precision methods of determining the constants of these transformers have been developed, and more of these transformers have been tested during the past year than in all the preceding years of the work of the Bureau. With the increasing development of high voltage power plants, especially in the West, these transformers have come into a place of great importance, as large amounts of power bought and sold are measured by their aid.

In addition to the usual work for other government departments, special work includes tests made for the National Museum, the Isthmian Canal Commission, the Commissioners of the District, and the general supply committee. Assistance has been rendered to the latter committee in the work of testing and inspecting manufacturers' samples of electrical goods and supplies.

Progress has been made on the design of labor-saving electrical testing instruments, which are soon to be built for the use of the Bureau.

## PHOTOMETRY.

Reference was made a year ago to the effort which the Bureau was making to secure uniformity in the value of the standard candle in England, France, and America, and to secure the general adoption of this international candle by the gas and electrical industries in this country. The proposal made by this Bureau was accepted by the national laboratories of England and France, and accordingly, on July 1, our unit of light was decreased by 1.6 per cent. This new value of the standard candle will hereafter be the standard for all photometric measurements in this country, both for gas and electric practice. It has been indorsed by engineering societies, and will gradually be recognized by the laws of the several States. Heretofore the "candle" has been spoken of in state laws and regulations as the standard of light, but different sperm candles differ so much that the unit so determined has been quite variable. Hereafter the "candle" as a unit should be understood to mean not the light of a sperm candle, but the value of the unit of light maintained by this Bureau.

A special investigation will be made during the next fiscal year of flame standards employed in photometry, for the purpose of determining their degree of reliability and, if possible, to improve one or more of them for the practical uses of gas photometry.

The Bureau has inspected and tested samples of electric incandescent lamps purchased by several of the government departments, amounting altogether during the past year to about 500,000 lamps. These tests are important, as they insure the delivery of good lamps. Without tests inferior lamps would certainly be furnished in many cases.

The standard specifications for carbon-filament incandescent lamps issued by the Bureau two years ago were revised during the year, and new specifications added for the new metal-filament lamps. These specifications have been prepared in conjunction with engineers representing the manufacturers and some of the government departments, and have been adopted as standard by the manufacturers and by the Government, and are used by many purchasers of lamps.

A considerable amount of work has been done during the year on color photometry, including the determination of the color values of various artificial illuminants in terms of average daylight, and the method of combining artificial illuminants to produce a color equivalent to that of daylight illumination.

Tests of gas and electric lamps to be used as standards by the gas and electric companies and by manufacturers have been made during the year in considerable numbers. No provision has yet been made for arc-lamp testing, owing to lack of space and insufficient personnel.

## DIVISION II.—WEIGHTS AND MEASURES.

The routine testing in the Division of Weights and Measures increased nearly 200 per cent over the previous year and the force, equipment, and space at its disposal were taxed to the utmost to meet the demands made upon the division.

### LENGTH MEASUREMENTS.

About twice the number of length measures were tested (approximately 570), including steel tapes, level rods, gages, and standard bars, over 80 per cent being either for the federal or for the state governments. The increase was due to the extraordinary demand of the Philippine government, which inaugurated a new weights and measures law on January 1, 1907. Other increases were due to the replacement of apparatus destroyed by fire in the building occupied by the Geological Survey, and to the further fact that practically all purchases now made by the Government are on specifications or according to samples submitted to the general supply committee.

Urgent requests have been made for the determination of the expansion of various alloys and materials, and to determine the dimensions of gages with a degree of accuracy recently made possible by the extraordinarily accurate gages now being manufactured by a Swedish firm. This work was necessarily deferred, but the development of apparatus for the testing of screw threads and the determination of expansions will be taken up energetically next year when new assistants are available.

The construction of the new meter comparator for length standards has reached a point where comparisons of standards in the old troughs or boxes is possible. The new iron carriage, the invar beam, and the microscope have been placed in position, and comparisons already made indicate a marked improvement in the results over those obtained with the old comparator. The box for comparing bars in ice and the arrangement for temperature control, including heating coils and water circulation of the double box, are not completed, but it is expected that they will be finished in the coming year.

During the year the Bureau received the platinum-iridium meter bar purchased from the French Government and graduated by the Société Genevoise. This bar was one of those made of the alloy of 1874, prepared by the French section of the international committee, because it contained a slightly larger percentage of certain metals than had been specified. It is of the same cross section as the prototype meters, and, with the graduation by the Société Genevoise and the comparison with the standards at the International Bureau, is in every other respect as satisfactory a standard as the prototype

meters. After being graduated it was compared and calibrated at the International Bureau of Weights and Measures, in Paris, and its coefficient of expansion determined.

Arrangements were completed during the year for comparing metal tapes with the bench standard, the tapes being supported at any desired points, and notice of this fact was given in a new edition of Bureau Circular No. 2.

Urgent demands were also made upon the Bureau for the standardization of master screws and preliminary designs of apparatus for such work were begun. The extreme difficulty of measuring the various dimensions of any screw with sufficient accuracy to state in advance that it will fit a certain nut is evident to anyone who has had experience in such work, and up to the present time no apparatus which more than approximately fulfills the desired conditions has been constructed. Nevertheless, the Bureau should be prepared to settle any dispute that may arise between manufacturers of screws and pipe threads as to compliance with the standard specifications for such threads, and every effort will be made to develop apparatus to satisfy the exacting needs of such work.

### MEASUREMENTS OF MASS.

As in other sections of the division, the routine testing of standards of mass showed a substantial increase of something over 50 per cent. This work, with the necessary cross-checking and intercomparison required to maintain satisfactory values for the secondary standards, left little or no time for the investigations which had been planned by this section. A large part of the routine work, as heretofore, was for the weights and measures inspection service of the several States.

It is gratifying to note a great improvement in the character of the weights now submitted for test over those submitted a few years ago. Solid one-piece weights protected by a coating of gold plating and made in accordance with the specifications of the Bureau may now be obtained from several manufacturers.

In response to the demand of manufacturers and state and local sealers tolerances for commercial weights, based upon those in use abroad, have been prepared, and will be announced in a circular some time during the next year.

The alterations, now practically completed, in the 25-kilogram precision balance will greatly add to the facility with which it can be used. What is most urgently needed in the form of equipment at the present time is a precision balance for loads of 200 grams and a quick-acting balance for loads of 30 grams. The maker of the small assay balance which has proved so satisfactory has been induced to design and construct a special balance of the desired capacity which it is hoped will be completed during the coming year.

A duplicate of a large part of the present equipment, as well as additional working space and assistance, must soon be had unless the division can be relieved of some of the demands upon it.

### VOLUMETRIC MEASUREMENTS.

During the year approximately 9,500 pieces of glass volumetric apparatus were tested, as compared with about 3,000 in the previous year. About 6,000 pieces additional were examined and rejected without actual test on account of defects of construction, design, etc. This apparatus consisted of flasks, transfer pipettes, measuring pipettes, burettes, and graduates, the larger portion being for government laboratories, and are of great importance, as in this way precision is provided for the general scientific and technical work of the Government.

In addition to the glass volumetric apparatus, 162 metal and paper capacity measures were tested. These included standards for several States and municipalities.

### HYDROMETRY.

Satisfactory progress was made during the year in placing the hydrometer work of the Bureau on an excellent basis.

Specifications for the construction and manipulation of hydrometers, as well as density tables for use in hydrometry, were prepared during the year and published in the form of circulars (Nos. 16 and 19). The primary standards of the Bureau were carefully calibrated and methods of testing developed. Over 1,000 hydrometers, including manufacturers' standards, alcoholometers used by the United States Internal-Revenue Service in the collection of duty on spirits, and hydrometers for various industrial uses, were tested.

### TIME MEASUREMENTS.

As a preliminary to the testing of watches for the public several sets of watches loaned by different manufacturers were tested as to their rates under varying conditions, in order to determine the tolerance to be allowed by the Bureau in issuing certificates. The test of the first lot was completed in July, 1908. A second lot of 50 watches, loaned directly by the manufacturers from stock, were next tested. This test was begun in November, 1908, and finished in April, 1909. A test of a third lot of 54, also loaned by the manufacturers but supposed to represent the better regulated watches of the regular product of high-grade watches, was begun in April, 1909, and is still in progress.

All of the above watches were tested for variations of rate with the five changes of position for which high-grade watches are usually

adjusted, viz, dial up, dial down, pendant up, pendant right, and pendant left. The effects of changes of temperature also were observed between 35° and 100° F. The variation of the rate throughout the day was ascertained by readings taken at different hours.

It is expected that the computations and regulations based upon them and to be followed in the testing of watches will be completed within the ensuing year. Before beginning the regular testing of watches, however, it will be necessary to construct a hot-and-cold room for temperature tests and to modify and extend the equipment.

The time on which the watch readings are based was obtained from a Riefler clock mounted in a constant temperature room in the basement of the physical laboratory. For one period of a month the correction of the clock gradually changed through less than 0.4 of a second without adjustment of the regulation being made during that period. The correction of the clock is obtained by comparison with the noon signal of the Naval Observatory received at the Bureau by wireless telegraph from the Washington Navy-Yard station. This service has been interrupted frequently for considerable periods during the year, due to changes being made in the sending station at the navy-yard, at which times it was necessary to obtain the signal by telephone.

### INSPECTION OF TRADE WEIGHTS AND MEASURES.

The fourth conference on weights and measures was held on December 17 and 18, 1908, and was well attended by delegates from different parts of the country. The reports of the delegates indicated that satisfactory progress is being made to improve the methods of inspection in New York, Massachusetts, Ohio, and Kansas, new and better laws having been enacted, while in Pennsylvania, Colorado, and New Jersey bills were considered by the legislatures. A recommendation was adopted urging an amendment to the pure-food law to require the weight, value, or number of the contents to be plainly marked on all commodities put up in sealed packages. This is of importance to the consumer in order that he may know exactly what he is purchasing. At present where sizes are not fixed by law there is nothing to prevent anyone from decreasing the size of the package put up without the purchaser being aware of the change. Evidence on all sides shows a widespread interest in the subject by individuals and various national organizations.

The appropriation of $10,000 made by Congress for an official investigation as to the extent that fraudulent weights and measures are used in different parts of the country is now available, and plans are completed for securing two experienced inspectors by civil-service examination to make a personal inspection in a number of cities and towns in various States. They will, however, practically

cooperate with the local official, if there be any, and endeavor to get information that will be first hand and reliable.

The general demand for better inspection of trade weights and measures, as well as the unification of the state laws on the subject, has caused a number of the States to call on the Bureau for the verification of both old and new standards. New Mexico, Kansas, and New York have purchased new equipment for their state sealers, while Massachusetts submitted for verification the standards furnished many years ago by the Federal Government.

## DIVISION III.—THERMOMETRY, PYROMETRY, AND HEAT MEASUREMENTS.

The tests completed during the year were as follows: 12,718 thermometers, including 504 high-temperature thermometers, 1,287 laboratory and special thermometers, and 10,927 clinical thermometers; 5 optical pyrometers, 22 thermocouples, 8 pyrometer galvanometers, 5 resistance thermometers, 159 flash-point and viscosity tests of oils, 41 standardized heat samples, and 6 other tests involving heat measurements; in all about 12,964 separate tests, an increase of nearly 40 per cent over the preceding year. The increase in the testing of the higher grades of thermometers was about 125 per cent, necessitating a very considerable increase in the amount of time devoted to this testing and emphasizing anew the need for a better establishment of the scale of temperature up to 500° C.

At the urgent request of chemists, engineers, and manufacturers this division, in cooperation with the Optical Division, is now furnishing standardized heat samples of known heat value for the standardization of combustion calorimeters. The practice of awarding large contracts for fuel on the results of determinations by combustion calorimeters is growing rapidly. The preparation of these heat samples, and the standardization of the finely graduated thermometers used in the tests, have already done much to increase their accuracy and to bring them to a uniform basis. Thus far the work is limited to furnishing analyzed samples of cane sugar of the highest purity. The determination of the heats of combustion of other substances, however, such as benzoic acid, naphthalene, and anthracene, is also under way.

By thus enabling chemists and engineers to test the accuracy of their apparatus and methods the Bureau is relieved of such routine testing as can be done as well in private laboratories, while accomplishing the important end in view, viz, the use of standardized apparatus and methods to enable different observers to obtain strictly comparable results. Accordingly, the determinations of the calorific values of fuels in this division have been limited to cases where the results of other observers disagree or where tests were made for another department of the Government.

In view of the urgent need for data for engineers, corporations, and public-service commissions, work has been done upon new apparatus for determining the heats of combustion of gases and intercomparison of the various types of calorimeters that are beginning to be widely used in the gas industry. This work will be carried forward rapidly during the coming year.

Upon request of the refrigeration industry the experimental work in determining the specific heats of calcium-chloride brines was completed during the year. This work is of importance to more efficient refrigeration engineering. Brines of very different chemical composition were included in this work, and two entirely different methods of calorimetry were used, the results by the two methods showing excellent agreement.

The use of cooling curves in metallurgical research is such that a description of methods used to obtain cooling curves of metals and other materials, with a brief analysis of their characteristics, has been published and will aid the application of such graphic methods to temperature work.

Pyrometers of almost every type used for the measurement of high temperatures are now being submitted for test. This is encouraging evidence of the increased application of scientific methods in those industries whose products depend upon the measurement or control of high temperatures. Until recently the eye of the workman, so subject to variable influences, was the only method in use in this country for estimating high temperatures; to-day pyrometers are found in use in rolling mills, in the ceramic and glass industries, in the manufacture of carbons, etc., and in various chemical operations. As nearly all the leading types of pyrometer are used in the laboratories of the Bureau, this division has been able to furnish information to representatives of many industrial plants about to introduce pyrometric methods in their works. This is an important feature of the work of this division.

An investigation was completed in this division, several years ago, upon the order of accuracy attainable with optical pyrometers in which the temperature of an incandescent body is estimated by the amount of light or heat emitted by it. Instruments of this type could, under proper conditions, be used to measure the highest attainable temperatures, and the several types of pyrometer examined showed excellent agreement even at the extreme temperature of the electric arc. Optical pyrometers were then just being introduced into use. They are now widely used in the industries, largely as a result of the Bureau's work. Since the light and heat radiated varies vastly with different materials, it becomes necessary to investigate the radiation from such substances as iron, copper, carbon, glass, fire clay, etc., to which these pyrometers are being applied in

the works. A research upon copper disclosed the fact that the radiation from the colder oxidized solid metal may exceed that from the clean surface of the molten metal, and that in some cases the indications of optical pyrometers may be in error by hundreds of degrees. The results are being published in the Bulletin.

The growing use of methods of temperature measurement based upon the change in electrical resistance of a platinum wire, and the high order of accuracy attainable by this method, led to an extended investigation of platinum resistance thermometry at high temperatures. The aim was to ascertain the advantages and limitations of such thermometers at high temperatures, the order of accuracy attainable, the effect of impurities in the wire, and the changes produced by exposure to high temperatures. These thermometers were also used to determine the melting and freezing points of certain metals, to determine the accuracy with which metals from the leading firms could be used to give "fixed points" for the high-temperature scale and for the calibration of pyrometers. This investigation was completed during the year and the results will soon be published. In order to improve the data needed for expressing temperatures on the absolute thermodynamic scale, the ultimate goal of all temperature measurements, the work of Joule and Thomson on the expansion of gases will be repeated and extended. This work has also a bearing on methods of liquefying gases, and hence on refrigeration, and on processes for the commercial separation of the oxygen and nitrogen of the air.

The theory of the Hampson gas liquefier was studied to obtain more precise insight into the working of this commonly used machine and the best conditions of economic operation. The results are now being published. Improvements in liquefying processes suggested by this investigation will be embodied in the apparatus now being designed.

The greatly increased demands for testing made on this division during the year have retarded some important investigations of fundamental importance to the usefulness of the division, such as the intercomparison of the several datiation laws, as a basis for the high-temperature scale; the establishment of the standard scale of temperature in the interval 100° to 500° C, and the construction and use of a standard gas thermometer for the determination of important fixed points of the temperature scale.

The number of clinical thermometers submitted for test during the year is 30 per cent greater than in the preceding year. The Bureau has continued the practice of loaning standard thermometers to the manufacturers of clinical thermometers, with most satisfactory results, the accuracy of practically all the product of American manufacturers, exceeding some 500,000 thermometers per annum, being thus controlled by standards loaned by this Bureau.

## DIVISION IV.—OPTICS.

During the year some important researches have been made in the Optical Division, which includes radiometry, spectrometry, polarimetry, and interferometry. Such researches are valuable in determining physical constants and the properties of materials, supplementing other methods used for this purpose. Besides the researches mentioned, many optical tests have been made for the Government and the general public, such as telescopic and photographic lenses, prisms, samples of glass, polariscopic apparatus, and sugar analyses.

### SPECTROSCOPY.

The investigations made by this section during the past year relate chiefly to improvements in the methods of testing optical instruments and materials, and to the methods of constructing reproducible primary standards of luminous intensity, of pure color, and of spectral intensity. A resolving power test for objectives and optical instruments was developed and described in the Bulletin. A new method of computing lens corrections has been devised and applied, and methods for the complete testing of high-grade photographic objectives have also been developed and outlined.

The study of the luminous equivalent of radiation was completed and published during the year. This problem underlies the theory of light measurement and the establishment of a rational absolute scale of luminous intensity. A method has also been developed for constructing a rational color scale and establishing primary standards of pure color. This is an important subject, and one which has many industrial and technical applications. Conducting helium has been further studied as a standard of total intensity and spectral intensity. A source giving discrete spectral lines of fixed known relative intensity is of great importance in the testing of photographic plates and other work.

A precision optical bench, specially designed for determining the oblique aberrations of high-grade lenses, has been installed and is in frequent use. Samples of optical glass were received for test, some of which were for use in large astronomical telescopes. Fifteen photographic plates were examined as to size and uniformity of grain and resolution of image. A series of secondary color standards was examined and compared with the primary standard colors. Many spectroscopic tests have been made for different chemists, and numerous intending purchasers have sought the advice of the Bureau before buying various optical instruments.

## RADIOMETRY.

The radiometric work of the Bureau includes the investigation of the laws of radiation of various substances, and also the instruments and methods used in such investigations. During the past year considerable time was devoted to the improvement and testing of radiation meters. This is of the greatest importance in the investigation of the radiation laws of a uniformly heated cavity, or so-called black body, in which the emissivity is independent of the composition of the inclosure. The accurate determination of the radiation constants of the black body is therefore of the highest importance, for it is the only standard of reference in numerous fields of research. One promising application of these radiation constants is in the extension of the scale of temperature beyond the present limits. With this end in view, a series of preliminary spectro-radiometric measurements have been made, the results of which would have been considered highly satisfactory when compared with previous work. However, since the object in view is the highest attainable accuracy with instruments and methods now available, this investigation is being taken up anew with an improved vacuum bolometer and with various other instrumental improvements.

In addition to this problem, further observations were made on the selective emission of solids, and on the lack of sensibility of the eye to red light when apparently watching two incandescent lamps in color. Additional data on "water of crystallization" was also obtained. This is an important problem in mineralogy, and, since the spectro-radiometric examination of minerals seems to be able to give us information not obtainable by chemical and other physical tests, further work has been undertaken on this subject.

## POLARIMETRY.

The work of this section has been marked during the year by an increased interest both by scientists and manufacturers, due to the fact that the Bureau is able to make immediate practical application of its research work in this growing field, thereby directing public attention to the results attained. The importance of applying the most accurate scientific methods of polarimetry to the collection of the revenue on sugar and to industrial processes is increasing. For this purpose, among other things, large quantities of pure sugar are indispensable. The problem of producing relatively large quantities of this material, of unexcelled purity, has been successfully solved by recrystallization in a vacuum. The demand on the Bureau for samples of this sugar is rapidly growing and many samples were sent out during the year for scientific use. The distribution of such samples

for standardization purposes marks an important step in optical measurements and calorimetry.

A further study of the quartz compensating polariscope has been completed and the results published in the Bulletin. In consequence of this work it now seems practicable to produce an instrument of the compensating type with an adjustable polarization angle as large as 15°, thereby giving sufficient light to permit of the direct polarization of the darkest sugars and molasses, and eliminating the litigation which results from the inaccurate methods now in use.

Much time has been spent in further study of methods of producing monochromatic light of great intensity. Suitable monochromatic sources, uniformly distributed throughout the visible spectrum, are indispensable for polarimetric measurements. A combination of sources and methods of purification has now been obtained, making it unnecessary to depend on the uncertain sunlight of this locality.

The cooperation with the customs service in increasing the accuracy of the tests on dutiable sugars has been continued with gratifying results. The regulations for this work prepared by the experts from the Bureau cover the methods, instruments, and procedure, and rigidly define the scientific basis upon which the revenue is collected. A new polarizing tube suitable for the customs service and commercial testing has been designed. One thousand three hundred and six analyses were made during the year.

## DIVISION V.—CHEMISTRY.

The Chemical Division has continued, with a somewhat limited force, to assist the different bureaus of the Government in checking their supplies and reaching conclusions, in some instances, on which to base future specifications. This work has grown since the establishment, during the year, of the general supply committee for the government departments. Much of the labor of testing supplies offered by bidders under the new system of purchase has devolved upon this Bureau, and the Chemical Division has had its full share. The routine testing of this division has more or less directly concerned every department and bureau of the service. Equally important with the testing is the study of the practical and scientific basis for specifications, the desirable qualities in materials, their accurate description in terms of physical and chemical properties which may be measured or tested by standard tests and analyses, standard methods of sampling, standard instruments and methods of testing, and finally the preparation of standard specifications for the guidance of the manufacturer and purchaser. This work should eventually lead to the adoption of such specifications for all materials purchased, and definite tests, so as to avoid the personal element in disagree-

ments. With the increased working force authorized by Congress for the coming year it is hoped to be able to meet most of the demands arising from this source.

Among the important studies that the Bureau has undertaken for the Government may be mentioned an extended experimental research upon certain properties of celluloid and other pyroxalin plastics for the Steamboat-Inspection Service. Besides several other investigations of less magnitude there were completed during the year about 2,116 tests and analyses, which may be classified broadly as follows: (1) Writing and printing inks, paper, and mucilage, 1,732, of which the larger part were of papers for the Government Printing Office; (2) lubricating and other oils, turpentine, paints, and related materials, 306; (3) miscellaneous materials, such as rubber, boiler compounds, brines, flooring compositions, boiler tubes, stereotype metal and other alloys, steels, glass, silks, and a variety of other materials, 78.

The distribution of analyzed and certified standard samples of steels and irons of definite composition has met with great success, the demand increasing 30 per cent over the previous year. This work, undertaken at the request of the American Foundrymen's Association, enables the metallurgical industry to keep constant and reliable check on their analyses, upon which depend so largely the success of the industry. The number of standard iron and steel samples furnished was 687, against 465 the year before. Provision has been made for adding largely to the variety of these analyzed samples in order to meet the growing calls from various directions. Cooperative relations have been entered into with the American Brass Founders' Association, at its request, with the view of furnishing analyzed samples of brasses and other alloys and the improvement of methods of brass analysis in that industry.

The Chemical Division will also cooperate with other divisions of the Bureau in certain very important problems, such as (1) the preparation and testing of pure materials used in the construction of standards of electromotive force; (2) the preparation of several substances of the very highest degree of purity and the determination of the physical constants of these substances for use as standards in calorimetric work; (3) the study of flame standards for use in photometric work; (4) the determination of the physical properties of the metals and alloys used in the arts.

## ENGINEERING INSTRUMENTS AND MATERIALS.

The standardization of engineering instruments and testing of materials showed a marked increase over the previous year. The demand for the calibration of engineering instruments and the determination

of the physical properties of materials has taken practically the entire time of the available assistants, thus restricting the attention given to investigations and the development of methods.

Much time and labor have been devoted to the collation of reliable information and data for the government departments and the public. The diffusion of such knowledge is of decided aid to industrial and engineering progress. In many cases, however, sufficient dependable information is not available, and the Bureau has been urged to take up investigations which would furnish it, including such subjects as methods of measuring gases at high velocities; properties of metals and alloys; standard specifications for leather belting; relative merits of oak and hemlock tanned leather; rubber hose; bookbinding cloths; relative life of iron and steel pipe; prevention and removal of efflorescence on brick walls; standard textiles; wool conditioning and sampling; efficiency of water meters, and discharge capacity of different sizes of pipe; relative merits of paper-testing apparatus; standard methods of testing paper and paper fibers, and dynamic tests of metals.

Many special researches have been delayed during the year by extensive demands along other lines. However, an investigation of the present methods of calibrating anemometers is progressing, and recent advances in aerial navigation accentuate the need for this work, especially for higher velocities. Further work upon bookbinding cloths has been completed and is available for publication. The results of this research have been practically applied in the binding of government publications, and book cloths are now being manufactured upon the standard specifications thus prepared. Many public libraries are buying their cloths for bookbinding upon these standard specifications and the demand for the reports of this investigation shows how quickly the value of such researches is appreciated and utilized. A study of methods of determining the absorption and adhesion of mortar to specimens of different absorption capacities is underway, the results of which are not yet ready for publication. Four American paper testers, for determining bursting strength, are being studied to determine the effects of humidity, rate of operation, intensity of clamping, and effect of imperfections. The verification of the phloroglucine method for determining the percentage of ground wood in papers is complete and ready for publication. While more exact than microscopic analysis by fiber staining, the phloroglucine is best applicable to grades of paper for which the microscopic method is fairly adequate. It was possible to begin the investigation of lubricants. The action of a standard oil tester is being studied to determine the conditions which influence its readings, the possibility of securing concordant results, and to investigate

the relation between viscosity, flash point, and coefficient of friction. This work is essential to the formulation of standard tests and specification for oils, a matter which deserves early attention.

The tests of engineering instruments and materials increased more than 100 per cent over the previous year, and included 52 tests of instruments, such as anemometers, manometers, paper testers, pressure gages, gas cylinders, and other apparatus; 84 samples of metals, such as steel and iron, electric welds (steel), manganese bronze, wire (special alloy), lead pipe, and flexible copper hose; 100 samples of building materials, such as cement, concrete, brick, composition flooring, rock, terra cotta, and wood; 3,191 samples of papers, textiles, and cordage; 96 samples of rubber and leather goods; 66 lubricants—machine, engine, and dynamo oils; and 42 miscellaneous materials, adhesives, etc., in all, 3,580 tests of materials, as compared with 1,716 in the preceding year. The increase in testing has been general in all branches of the work, the most marked increase being in textiles and papers.

Recent additions to the equipment will enable the Bureau to undertake some valuable investigations. Among the new apparatus acquired for metal investigations are a Keep hardness tester, a Ballentine hardness tester, a Brinell hardness tester, a Shore scleroscope, a cold-bending machine (motor driven), and a Souther alternating stress machine. A high-grade microscope, with a mechanical state, has been added to the equipment for fiber work. A Riehlé cement tester and a 12-spool yarn reel have been delivered, and orders are outstanding for a Turner-Landgraf alternating-impact machine, a cement permeability apparatus, a 1,000,000-pound special Riehlé crushing machine, a 230,000-pound improved Emery testing machine, 150-meter kilogram torsion machine, a Danto Roguet conditioning apparatus, a Corté yarn reel, and Corté conditioning oven.

## LIBRARY.

An important part of the equipment of the Bureau is the library, which now contains 4,941 technical and scientific works, mainly in physics, chemistry, mathematics, and engineering. During the year 380 volumes were added to the library and 180 periodical publications were regularly received.

The library is catalogued upon the classification used at the Library of Congress, the printed cards issued by that library being used as far as available. The facilities of the scientific libraries in Washington are also available for reference. Access to the complete literature in any technical subject is essential to the best work, especially in new investigations.

## PUBLICATIONS.

During the year 23 technical papers relating to standards and precision measurements were published, giving the results of researches and investigations conducted by the Bureau of Standards. Six bureau circulars were published giving information as to methods of testing specifications for standards and measuring instruments and regulations in regard to their verification, i. e., Circular 13, "Standard specifications for the purchase of incandescent electric lamps" (revised to include the new high-efficiency filament lamps); Circular 14, "Analyzed irons and steels—Methods of analysis;" Circular 15, "A proposed international unit of light;" Circular 16, "The testing of hydrometers;" Circular 17, "Magnetic testing;" and Circular 18, "United States standard sheet-metal gauge." A new edition of the chart of the international metric system was also issued.

## BUILDINGS AND GROUNDS.

The contract for the new laboratory building authorized by Congress was awarded early in the year, and the construction is nearly completed. Plans are now being drawn for the installation of the apparatus and machinery. The new laboratory harmonizes in style, appearance, and location with the other buildings, and has been designed in details to meet the needs of the work.

The new laboratory has four stories and is of fireproof construction, of brick trimmed with limestone. The first floor is especially suitable for heavy testing apparatus and for work requiring great stability. The large testing machine will be installed in the new building. It is expected that the laboratory will be ready for use early in 1910.

The grading has been continued along the lines previously laid out, but additional roadway and walks will be needed for the new building.

## SUMMARY OF TESTS.

The work of the Bureau involves, among other things, a large amount of testing of standards, measuring instruments, and materials. A certain amount of this work is already organized upon an accurate routine basis. Much of it, however, involves investigation of the scientific principles underlying the test, a study of existing methods, and the development of new standard tests of known accuracy. In such cases the research which must precede the actual testing is a most important function of the Bureau. For the test a reasonable fee is charged, except when made for the National or State Governments. The corresponding amounts for government testing are of interest, however, and are added to the statement of tests which follows:

NUMBER AND VALUE OF TESTS COMPLETED, FISCAL YEAR ENDED JUNE 30, 1909.

| Nature of test. | For Government. | | For public. | | Total. | |
|---|---|---|---|---|---|---|
| | Number. | Value. | Number. | Value. | Number. | Value. |
| Length | 460 | $1,091.10 | 106 | $257.80 | 566 | $1,348.90 |
| Mass | 1,635 | 700.55 | 463 | 290.95 | 2,098 | 991.50 |
| Capacity | 10,386 | 3,196.15 | 379 | 322.90 | 10,765 | 3,519.05 |
| Temperature | 3,812 | 1,521.25 | 9,129 | 1,926.37 | 12,941 | 3,447.62 |
| Optical | 1,287 | 1,304.00 | 29 | 58.00 | 1,316 | 1,362.00 |
| Engineering | 2,082 | 7,190.10 | 122 | 269.63 | 2,204 | 7,459.73 |
| Electrical | 151 | 531.70 | 314 | 1,159.70 | 465 | 1,691.40 |
| Photometry | 2,668 | 5,226.20 | 1,256 | 336.50 | 3,924 | 5,562.70 |
| Chemical | 1,972 | 7,681.26 | 549 | 925.60 | 2,521 | 8,606.86 |
| Miscellaneous | 1,176 | 900.75 | 113 | 101.60 | 1,289 | 1,002.35 |
| Total | 25,629 | 29,343.06 | 12,460 | 5,649.05 | 38,089 | 34,992.11 |

Besides the foregoing the Bureau inspected 628,400 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to $3,142 additional, making the total value of work done for the Government $32,485.06.

The number of tests made for the Government in the fiscal year 1909, exclusive of lamps inspected at factory, was 159 per cent greater than in the preceding year, and the number of tests for the public was 15 per cent greater, the increase in tests for both Government and public amounting to 84 per cent.

The receipts for tests were as follows:

| | | |
|---|---|---|
| Total receipts, 1909 | | $6,001.06 |
| Received prior to July 1, 1908, for tests completed in fiscal year 1909. | $90.98 | |
| Outstanding fees | 124.40 | |
| Canceled test and refunds | 16.92 | |
| | | 232.30 |
| | | 6,233.36 |
| Received for tests in progress at close of fiscal year 1908–9 | | 584.31 |
| Fees for tests completed, 1908–9 | | 5,649.05 |

## FINANCIAL STATEMENT.

The following statement shows the amount and object of each appropriation provided for the Bureau for the fiscal year 1909, the disbursement during the year, the amount of unfilled and unpaid orders at the close of the year, and the unexpended balance remaining at the close of business June 30, 1909:

| Appropriation. | Appropriated. | Disbursed. | Liability. | Balance. |
|---|---|---|---|---|
| Salaries | $141,540.00 | $138,765.11 | ..... | $2,774.89 |
| Equipment | 41,000.00 | 30,131.53 | $10,684.92 | 183.55 |
| General expenses | 15,000.00 | 12,737.49 | 1,221.65 | 1,040.86 |
| Grounds | 3,000.00 | 2,997.22 | ..... | 2.78 |
| Total | 200,540.00 | 184,631.35 | 11,906.57 | 4,002.08 |

The following statement shows the condition of the appropriations for the two fiscal years preceding 1909 at the close of business June 30, 1909:

| Appropriation. | 1907. | | | | 1908. | | | |
|---|---|---|---|---|---|---|---|---|
| | Appropriated. | Disbursed. | Liability. | Balance. | Appropriated. | Disbursed. | Liability. | Balance. |
| Salaries | $111,440.00 | $108,399.59 | ..... | $3,040.41 | $130,620.00 | $123,874.24 | ..... | $6,745.76 |
| Equipment | 41,000.00 | 40,502.49 | $429.73 | 67.78 | 41,000.00 | 40,051.21 | $607.13 | 341.66 |
| General expenses | 15,027.50 | 15,023.48 | ..... | 4.02 | 15,000.00 | 14,883.97 | 19.26 | 96.77 |
| Grounds | 3,000.00 | 3,000.00 | ..... | ..... | 3,000.00 | 2,982.86 | ..... | 17.14 |
| Total | 170,467.50 | 166,925.56 | 429.73 | 3,112.21 | 189,620.00 | 181,792.28 | 626.39 | 7,201.33 |

Respectfully,

S. W. STRATTON, *Director.*

To Hon. CHARLES NAGEL,
*Secretary of Commerce and Labor.*

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